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DIVISION OF AGRICULTURAL SCIENCES
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An Estimation of Returns to Irrigation Water in Israel with Reference to Seawater Desalting Proposals

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AN ESTIMATION OF RETURNS TO IRRIGATION WATER IN ISRAEL WITH REFERENCE TO SEAWATER DESALTING PROPOSALS

by

Ezra Sadan[1]

Introduction

Growth and Water Resource Development in Israel

The growth and development of Israel's agriculture in the 1950's were closely associated with water resource development projects and the implementation of irrigation throughout the northern semiarid regions and, to a limited extent, the southern arid regions of that country. A 370-percent rise in the value of Israel's current agricultural production from 1949 to 1959 was associated with an approximate 450-percent rise in water use in agriculture and the area under irrigation. The latter rate was twice as high as those referring to the growth of Israel's farm employment and its farm capital endowment during the same period. However, in the 1960's, growth and development took a new course. Farm capital accumulation and the growth in the farm production level continued at a slower pace. Yet, farm employment tended to decline, while water use in agriculture was maintained at a more or less constant level.[2] Water use leveled off mainly due to the near exhaustion of Israel's "conventional" sources; that is, the relatively inexpensive ones, such as rivers and springs, groundwater, etc.[1] The water projects at that stage consisted of some major regional and superregional plants. Later, in 1965, these plants were connected into an integrated national water system through Israel's National Water Carrier which conveys water from the Jordan in the north down to the arid Negev in the south. Water resource development plans beyond that point do involve some conventional but relatively more expensive projects, but they eventually end up with the "ultimate" source, namely seawater desalting.

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[1] Lecturer, Department of Agricultural Economics, Faculty of Agriculture, The Hebrew University of Jerusalem, Rehovot, Israel; presently Visiting Associate Economist of the Experiment Station and on the Giannini Foundation.

[2] Israel, Bank of Israel, Annual Report, 1959 (Jerusalem, 1960), and subsequent annual issues.

Israel, Central Bureau of Statistics, Statistical Abstract of Israel, 1959 (Jerusalem, 1960) and subsequent annual issues.

Israel, Ministry of Agriculture, "The Minister's Annual Report to the Knesset" (Tel Aviv, 1960) and subsequent annual mimeographed reports.

Water Allocation

Water allocation in Israel is subject to state control. For all practical purposes, water in Israel could be considered as a nationalized resource allocated through an elaborate system of quotas. Water allotments allocated through this nonmarket mechanism are, in principle, subject to reassessment and reallocation. Yet, in practice, farmers tend to visualize their allotments as if they were legally established quota rights. As long as new water resources were made available through the process of conventional water resource development mentioned above, the authorities (consisting of a water commission and Israel's Ministry of Agriculture Planning Center) were able to avoid the question of water reallocation. At the present, however, and even more so in the future, reallocation is bound to become an acute and serious problem. It must be realized that the difference between the past and the future in this respect is merely a question of degree. The nonmarket mechanism in the past did not result in an optimal allocation of water among the various units of

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1/ Dan Yaron, The Demand for Water by Israel Agriculture, Department of Agricultural Economics, The Hebrew University of Jerusalem (Rehovot, Israel, 1966), p. 2.

water consumers. If the allotment system had allowed for transactions in "quota rights" or quota transfers, water reallocation would have taken place.[1] Transactions of this type which did take place in the past were limited to the local level among family farmers in moshav villages, for instance.

In the future, disparities due to an inefficient water allocation mechanism may become larger for various reasons. Gaps between the marginal returns to water in two existing units, such as two farm units, may grow wider as a result of dissimilar patterns of specialization or due to different patterns of growth and development. Considering larger sections of the economy rather than economic units, such as households, industrial plants, or farms, we note that differences in growth patterns may eventually result in a growing disparity between marginal returns in the urban-industrial section and those in the farm sector. Furthermore, with a given water supply--a "perfectly" rigid system where quotas are nonnegotiable among holders or between holders and the authorities--the system may be incapable of accommodating some new elements, such as new irrigable crop or new water-consuming industrial plants. New crop or industrial products are bound to be left out if they cannot be incorporated in existing quota-holding economic units. The elements left out will eventually include new economic units, such as new farms, new industrial firms, and, more important, new households. In Israel, in particular, such inflexibility would have ruled out immigration and settlement projects which may carry high social or national values.

The Israeli system, far from being a perfect imitation of the market mechanism, is not really a perfectly rigid system. Yet, it does involve some rigidities which are liable to result in some serious difficulties once new water resources are no longer available. Short in new supplies, the authorities will have to consider reallocation in order to cope with the new demands for water. But, as pointed out by Milliman, "it is most common for most analysts, when faced with the problem of water shortage, to think first about the technology and engineering aspects of obtaining new water supplies," tending to "neglect the economic principles of resource allocation."[1/] The Israeli case is no exception to that rule. The reaction to the prospect of water shortage was a search for new resources rather than an attempt to find ways and means to improve the institutional framework. This is the background of the special interest in the ultimate source--a seawater desalting plant.

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[1] M. Weisbrod, Regional Planning of Agricultural Branches in Israel--An Application of a Linear Programming Model, Agricultural Planning Center and the Department of Agricultural Economics, The Hebrew University of Jerusalem (Jerusalem, 1968) (in Hebrew).

The Costs of Desalted Seawater

A nuclear dual-purpose plant, capable of desalting 100 million gallons per day (MGD), has been considered as a possible Israeli-United States project in the last few years.[2/] Estimates of the costs of the type of plant proposed were proposed by the Kaiser Engineering Corporation in 1966.[3/] The imputed costs per 1,000 gallons in a revised version of that report were found to be in the vicinity of 25-68 cents when the rates of fixed charges (interest and depreciation) were stipulated at the levels of 5 and 10 percent,

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[1/] J. W. Milliman, "The Economics of Water Production Using Nuclear Energy," in Water Production Using Nuclear Energy, ed. by R. G. Post and R. L. Scale (Tucson: The University of Arizona Press, 1966), pp. 49-73.

[2/] Zvi Zur, "A Survey of the Water Desalination Project," Economic Quarterly, Vol. 12, No. 47 (July, 1965) (in Hebrew).

[3/] "Engineering Feasibility and Economic Study for Dual Purpose Electric Power-Water Desalting Plows for Israel" (unpublished report), by Kaiser Engineers in association with Catalitic Construction Company.

respectively.[1] These figures were consistent with the ones derived for similar projects, such as the Bolsa Chica in southern California. The costs of desalted water appear to be rather high as compared with Israel's supported price of water which amounts on the average to 5 cents per 1,000 gallons, or even the price attached to water in some "gray market" transactions in water rights which fall in the vicinity of 15 cents.[2] These transactions, we recall, take place at a local (village) level. The apparent gap between the gray market and the above figures becomes wider if the cost of conveyance is taken into consideration. An average rate of approximately 10 cents per 1,000 gallons is indicated by the planners as the conveyance costs associated with the desalting plant under consideration. Thus, the anticipated costs are three times as high as the gray market price.

An Inquiry into the MVP of Water

In this context it might be suggested that, at least for the present, further consideration of economic costs and benefits of water desalting in Israel is redundant. However, no consensus to that effect has ever been reached among the Israeli and the American experts concerned with the proposed Israeli-United States project. Differences of opinion, in this respect, are associated with two fundamental issues. The first issue concerns the marginal returns to water in Israel's agriculture with reference to the "state of technology," the real rates of factor remuneration, and the respective patterns of change through time. The second issue concerns some intangible benefits attributable to Israel's settlement projects related to water allocation.

---

[1] Considering a dual-purpose electric power and water desalting plant, this cost analysis necessarily requires the allocation of joint costs. Interested in rough indicators of the magnitude involved, we accept the figures arrived at in the Kaiser study regardless of the degree of accuracy of the procedures involved.

[2] Most naturally, details of these transactions are not easily recorded. The figures were approximated on the basis of unpublished information; see Ezra Sadan, "Problems of Development of Water Resources in Israel," Economic Quarterly, Vol. 14, No. 54-55 (October, 1967) (in Hebrew).

The marginal returns to water are discussed in the second and third parts of this paper. Formulae arrived at through a simplified model drawn in the second part are applied in the estimation of the present marginal returns and the respective future trend in the third part. The latter part includes a discussion of factor mobility and factor pricing in the present as well as the case of change in output and factor prices through time. The fourth and last part presents an evaluation of the primary benefits attributable to water desalting. A brief discussion of desalted water as a dilutant and an appraisal of the major intangible benefits attributable to desalting is also presented in that part. Examining the intangible benefits, we reexamine the repercussions of the allocation mechanism just described.

Technology, Prices, and the Marginal Returns to Water

Returns to water--envisaged as the only "fixed factor" in agriculture--are considered in the following sections within the framework of a simplified model. The fundamental and strongest assumption underlying this model is that of a flexible allocation mechanism, free of internal or external factor-rationing.

It is assumed that factors other than water are perfectly mobile. Within this framework, returns to the fixed factor at the present are undoubtedly related to the state of technology and the relative prices of the variable factors. Future trends in these returns should be similarly related to the corresponding trends in technology and prices.

The Value of the Marginal Product of Water at the Present

Let us consider the input-output relationships in agricultural production in terms of an aggregate function of the Cobb-Douglas type. Let x_{ot} stand for the output level of a definite group of farmers--possibly the entire farm sector--in year t, measured in value terms at the farm product price level of a base period $t = o$. Let the array of factors employed in the production of x_{ot} consist of $m - 1$ "variable factors" and a single "fixed factor," supposedly water. The input level of the *i*th factor of production in year t is indicated by x_{it}, $i = 1, 2, \ldots, m$. Let m denote the fixed factor, x_m, indicating its fixed input level, $x_{mt} = x_{mt-1} = \ldots = x_{mo} = x_m$. The production function takes the following form:

$$x_{ot} = \alpha_o \prod_{i=1}^{m} x_{it}^{\alpha_i} e^{\gamma t} \qquad (1)$$

where

α_i = productive elasticity of the *i*th factor

γ = rate of a neutral, disembodied technical change

and

α_o = general constant term.

It is assumed that $\alpha_i > 0$ and $\sum_{i=1}^{m} \alpha_i = 1$. Thus, all marginal productivities are positive, and the production function is homogeneous of the first degree.[1/]

[1/] The proposition of linear homogeneity implying that the product is "completely exhausted" is quite common in the analysis of large sections of the economy. It underlies the studies of Israel's farm sector by A. Gaaton, Capital Employment and Output in Israel from 1950 to 1959 (Jerusalem: Bank of Israel, 1961), and Israel, Economic Planning Authority, The Growth of the National Economy in the Past and Future Development (Jerusalem, 1960).

It is also consistent with the outcome of the production function analysis of various farm groups in Israel. For example, see Sadan, op. cit.; also Capital Formation and Growth of the Kibbutz Settlement, The Hebrew University of Jerusalem (Rehovot, Israel, 1967); and "Capital Formation and Growth of the Israeli Cooperative Farm," American Journal of Agricultural Economics, Vol. 50, No. 4 (November, 1968), p. 97.

The farm sector, as a whole, notwithstanding a specific group of farmers are assumed to be "unimportant" customers on the markets for the variable factors of production. As far as this sector of the economy is concerned, prices of labor, the services of the various reproducible real assets, raw materials, etc., are given.

Assuming that the group of farmers concerned attains and maintains a level of the marginal product of factor i, denoted V_i, which equals the corresponding factor price level, we arrive at the following equation:[1]

$$V_{it} = \alpha_i \frac{x_{ot}}{x_{it}} \frac{W_{ot}}{W_{oo}} = W_{it} \tag{2}$$

where W_{it} and W_{ot} stand for the absolute price levels prevailing in period t of the *i*th input and the output correspondingly. Thus, W_{oo} indicates the absolute price of a unit farm product in the base period o. Following equation (2)

$$\alpha_i = \frac{W_{it}\ x_{it}}{(W_{ot}/W_{oo})\ x_{ot}} \tag{3}$$

and applying Euler's theorem:

$$V_{mt} = \frac{(W_{ot}/W_{oo})\ x_{ot}}{x_m} - \sum_{i=1}^{m-1} \frac{W_{it}\ x_{it}}{x_m}, \tag{4}$$

thus suggesting that the value of the marginal product of a fixed factor equals the "average residual value," that is, the difference between the "value of the average product" and the "average (variable) factor remuneration," where the averages referred to are imputed per unit fixed factor. The application of equations (3) and (4) is a common procedure in the approximation of "factor shares" and the determination of the contribution of a "residual" factor.

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[1] See discussion on the limitation of the model, infra, p. 41.

Future Values of the Marginal Product of Water

Considering future trends, equation (2) could be solved for x_{it}:

$$x_{it} = \alpha_i P_{it} x_{ot} \tag{5}$$

where $P_{it} = \frac{W_{ot}}{W_{it}}$ (i = 0, 1, 2, ..., m - 1), and assuming $W_{oo} = 1$.

Substituting the variables, x_{it} through $x_{m-1,t}$, in equation (1) by their respective values according to equation (5) and solving for x_{ot}, we arrive at:

$$x_{ot} = \alpha'_o \prod_{i=1}^{m-1} P_{it}^{\alpha_i/\alpha_m} e^{(\gamma/\alpha_m)t} x_{\dot{m}} . \tag{6}$$

where

$$\alpha'_o = \alpha_o^{1/\alpha_m} \prod_{i=1}^{m-1} \alpha_i^{\alpha_i/\alpha_m} .$$

Following equations (3) and (6) we arrive at:

$$\bar{V}_{mt} = \alpha_m \alpha'_o \prod_{i=1}^{m-1} P_{it}^{\alpha_i/\alpha_m} e^{(\gamma/\alpha_m)t} \tag{7}$$

where $\bar{V}_{mt}$ stands for the "real" value of the marginal product being measured at the base period farm product price level; that is, in monetary units, the power of which on the market for farm products remains intact through time.

Differentiating equation (7) with respect to t, then dividing the outcome by $\bar{V}$, we arrive at:

$$\frac{\dot{\bar{V}}}{\bar{V}} = \frac{1}{\alpha_m} (\gamma + \sum_{i=1}^{m-1} \alpha_i \frac{\dot{P}_i}{P_i}) \tag{8}$$

where $\frac{\dot{\bar{V}}}{\bar{V}}$ stands for $\frac{\partial \bar{V}}{\partial t} \cdot \frac{1}{\bar{V}}$, the annual percentage change in $\bar{V}$, etc. Assuming that

$$W_{it} = W_{io}\, e^{\nu_i t} \qquad \text{for } i = 0, 1, \ldots, m - 1, \tag{9}$$

equation (8) is rewritten as follows:

$$\frac{\dot{\bar{V}}}{\bar{V}} = \frac{1}{\alpha_m} (\gamma - \sum_{i=1}^{m-1} \alpha_i \beta_i) \tag{10}$$

where $\beta_i = |\nu_o - \nu_i|$, contemplating $\nu_i > \nu_o$, that is, a decline in the relative price of the farm product.

Let $\bar{\beta}$ stand for the annual percentage change in the weighted relative price $\bar{P}_t$.[1]

$$\bar{P}_t = \prod_{i=1}^{m-1} P_{it}^{\alpha_i/(1-\alpha_m)}, \tag{11}$$

then equation (6) could be written as follows:

$$x_{ot} = \alpha'_o\, \bar{P}_t^{(1-\alpha_m)/\alpha_m}\, e^{(\gamma/\alpha_m)t}\, x_m. \tag{12}$$

---

[1] Note that $\sum_{i=1}^{m-1} \frac{\alpha_i}{1 - \alpha_m} = 1.$

Restating equations (7) through (9) accordingly, we arrive at a simplified version of equation (10):[1]

---

[1] Since equation (9) holds for $i = 0, 1, \ldots, m - 1$, the pace of change in the relative price of the farm product is envisaged and treated in the simplified model as if it were an exogenous element. An enlarged model might, and should, have included a demand function for the farm product. Consider, for instance, the following demand function:

$$x_{ot} = \eta_o \bar{P}_t^{-\eta_p} y_t^{\eta_y} N_t^{\eta_n} \qquad (13)$$

where

$\bar{P}_t$ = relative price of the farm product

y_t = real income per capita in year t

and

N_t = corresponding population-size figure.

The coefficients η_p, η_y, and η_n stand for the absolute value of the price elasticity and the income and population-size elasticities, respectively, and η_o is a constant term. Assuming that $\bar{P}_t$ in equation (13) is identical with the one incorporated in equation (12)--now visualized as a supply function--we could replace $\bar{P}_t$ in equation (12) by the value arrived at solving equation (13) for $\bar{P}_t$. The restated equation (12) differentiated with respect to x_m and with respect to t, then divided by $\bar{V}$ gives rise to the following equation:

$$\frac{\dot{\bar{V}}}{\bar{V}} = \frac{1}{1 - (1 - \eta_p)\,\alpha_m} [\gamma\eta_p + (1 - \alpha_m)\,(\eta_y \frac{\dot{y}}{y} + \eta_n \frac{\dot{N}}{N})]. \qquad (14)$$

It could be shown that, as long as $\eta_p = 1$, equations (14) and (15) are algebraically consistent. It must be pointed out, however, that the simple model has been adopted with no reference to a particular enlarged model, including the one contemplated here.

$$\frac{\dot{\bar{V}}}{\bar{V}} = \frac{1}{\alpha_m} [\gamma - (1 - \alpha_m) \bar{\beta}].^{1/} \qquad (15)$$

Equations (10) and (15) suggest that the percentage change in the real value of the marginal product of a fixed factor is positively associated with the rate of technical change. It is negatively associated with the rate of change of the relative prices, contemplating a decline in the price of the farm output relative to price of the variable farm inputs. To the extent that the percentage change in the total factor productivity exceeds the percentage change in prices, that is, $\gamma > (1 - \alpha_m) \bar{\beta}$, the value of the marginal product of the fixed factor is bound to rise.

Water-Saving Technology, Prices, and the Marginal Returns to Water

The technical changes discussed in the following sections are commonly known as "water saving" practices or techniques. For the sake of clarity, however, we find it useful to distinguish between three major types of changes of that sort. The first denoted as "water substituting" is nonneutral (with respect to factor substitutability), and it does not affect total factor productivity. The second referred to as water saving is neutral and affects total factor productivity. The third type, referred to as a joint technique, is a combination of the first two. As in the previous sections, the discussion is intended to emphasize possible technology-price interrelationships at the industry level.

Water Substitution.--Subject to an implicit assumption of unitary elasticities, the model outlined above allows for factor substitution, the degree

---

1/ The percentage change in the real value of the marginal product of the residual factor measured at the base period factor price rather than the farm product price level will be: $\dot{\bar{V}}/\bar{V} - \bar{\beta}$.

of which is independent of the state of technology. Technical change in this model is neutral, leaving factor shares and the rates of factor substitution intact.[1/] Within this framework, technological developments affecting factor substitution, such as the introduction of water-substituting techniques, are necessarily interpretable in terms of changes in the parameters of the model which have been considered so far as given constants.

The case considered in this section concerns an innovation which allows for the replacement of the production technology characterized by the original production equation (1) by a new technology which could be summarized by a production equation of an identical form but with different parameters. The new technology is water substituting in the sense that, given the input combination, the marginal rates of substitution of other factors for water are higher than the respective original ones. This implies a smaller elasticity of water in the new equation, say, $\alpha^*_m = \alpha_m k$, $0 < k < 1$. It is also assumed that the rest of the new production elasticities $\alpha^*_1, \alpha^*_2, \ldots, \alpha^*_{m-1}$, are equiproportionally higher than the respective original ones, $\alpha^*_i = \alpha_i \frac{1 - \alpha_m k}{1 - \alpha_m}$, so that the property of linear homogeneity is retained. The remaining parameters of the new equation, α_o and γ, are identical with their respective analogues in the old one. The new technique is envisaged as a "technological improvement" in the sense that the output rendered by the combination of inputs

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[1/] The marginal rate of substitution of factor i' for factor i in this model, $\frac{\alpha_{i'}}{\alpha_i} \frac{x_{it}}{x_{i't}}$, depends upon the relative factor intensity alone and is independent of the prevailing state of technology.

employed before its implementation is lower than the one attributable to the same combination after implementation. This will be the case where the residual factor--water--is a relatively "scarce resource."[1]

The actual adoption of the new technique depends upon the corresponding prospected change in the farm operators' net returns. In our simplified model the net return is identifiable with the residual in the total revenue. Thus, the condition for the implementation of the new technique is specified as follows: Let x'_{ot} and x''_{ot} stand for the equilibrium output in period t under the old and the new technology, respectively. These two values are solved for employing equation (12) under the assumption the $\bar{P}_t$ is given at a level indicated by $\bar{P}'_t$. Define r'_t as: $r'_t = \frac{x''_{ot}}{x'_{ot}}$ and the condition for implementation will be $r'_t \geq \frac{1}{k}$, where k, we recall, indicates the ratio of the new (and smaller) residual factor elasticity to the old one.

The concept of a price level $\bar{P}_t$, which is the function of time only, is an inappropriate simplification where intraperiod quantity changes are concerned. If output price elasticity is finite, the equilibrium output level x''_{ot} cannot really be materialized. Let x^{**}_{ot} indicate the equilibrium output level finally attained, let $\bar{P}^{*}_t$ denote the corresponding price level, and R_t stand for the ratio of the attainable output under the new technology over the one attainable under the old one, $R_t = \frac{x^{**}_t}{x'_t}$. It could be shown that the ratio R_t is generally smaller than r'_t. Should output price elasticity be unitary, then $r'_t = [Q(t)]^{1/\alpha_m k}$ and $R_t = [Q(t)]$; thus, $r'_t = R^{1/\alpha_m k}$, that is, $r'_t > R_t$.[1] In other words, the condition $r'_t \geq \frac{1}{k}$ does not rule out a reduction in the operators' net return which may occur if $R_t < \frac{1}{k}$.

---

[1] Let $\bar{x}_t$ stand for $\bar{x}_t = \prod_{i=1}^{m-1} x_{it}^{\alpha_i/(1-\alpha_m)}$. (Note that $\alpha_i/(1-\alpha_m)$ is not affected by the implementation of the innovation in question.) We consider x_m to be a relatively scarce resource when $\frac{\bar{x}_t}{x_m} > 1$. In that case, given the input combination x_{1t} through $x_{m-1,t}$ and x_m, the output level with the new technique will be $\left(\frac{\bar{x}_t}{x_m}\right)^{(1-k)\alpha_m}$ higher than the one attainable through the old one.

The operators view prices as given; hence, their initial assessment of the desirability of adopting the new technique depends upon the ratio r'_t rather than R'_t. When the process of implementation is completed, the farmers may find it desirable to maintain the new technique rather than return to the old one even when $R_t < \frac{1}{k}$. This may be the case for the following reason: Let x^*_t stand for the equilibrium output under the old technology but at the new (and lower) price level $\bar{P}^*_t$, and let r^*_t stand for the ratio of x^{**}_t over x^*_t, $r^*_t = \frac{x^{**}_t}{x^*_t}$. It could be shown that $r^*_t = [Q(t)]^{1/\alpha_m}$; thus, $r^*_t = R_t^{1/\alpha_m}$.

Should the farmers be organized as one economic entity, they would have taken the ratio R_t rather than r'_t or r^*_t into consideration.[2] Yet, in the prevailing socioeconomic setup, the "unorganized" farmer may adopt a new technique which consequently results in a reduction in their net returns; this may happen because $r'_t > r^*_t > R_t$. A reduction in the net returns is interpreted in our model as a decline in the value of the marginal product of the residual factor. Hence, the implementation of water-saving technique via water substitution may result in a decrease rather than an increase in the value of the marginal product of water.

---

[1] Following equation (12), $Q(t) = [\alpha''_o \bar{\alpha} \bar{P}'_t e^{\gamma t}]^{(1-k)}$, where $\bar{\alpha} = \prod_{i=1}^{m-1} \alpha_i^{\alpha_i/(1-\alpha_m)}$, and $\alpha''_o = \alpha_o \left(\frac{1-\alpha_m k}{1-\alpha_m}\right)^{1-\alpha_m k/(1-k)}$.

[2] Monopolistic practices have been ruled out in order to simplify the argument.

As indicated above, both r'_t, r^*_t, and R_t are functions of t. Hence, the fulfillment of this condition $r'_t \geq \frac{1}{k}$ in period t does not necessarily imply that this condition will be maintained in subsequent periods. The change in either r'_t, or r^*_t, or R_t through time depends upon the relative magnitude of γ, the rate of technical change, and $\bar{\beta}$, the absolute value of the rate of change in $\bar{P}_t$. If $\gamma > \bar{\beta}$, the three ratios are bound to rise. Yet, if $\gamma < \bar{\beta}$, the ratios are doomed to decline.[1]

In the former case, "residual factor-substituting" techniques will eventually be implemented. In the latter case, the techniques are bound to be abandoned. In other words, the adoption of new techniques intended to "save" water at the expense of extending the use of the variable factors depends upon the rate at which the real price of these factors tends to rise relative to the rate of technological improvement taking place. When the factor prices rise at a rate higher than the rate of technical change, residual factor-substituting techniques will eventually disappear.

Water Saving.--Water-saving practices or techniques differ from water-substituting ones in two respects:

1. The implementation of the former, unlike the latter, does not involve any significant change in factor substitutability. Hence, within the framework of our model, the adoption of a water-saving technique leaves the production elasticities intact.

---

[1] Note that $\frac{\dot{r}'}{r'} = \frac{1}{\alpha_m k}\frac{\dot{Q}}{Q}$, $\frac{\dot{r}^*}{r} = \frac{1}{\alpha_m}\frac{\dot{Q}}{Q}$, $\frac{\dot{R}}{R} = \frac{\dot{Q}}{Q}$, and $\frac{\dot{Q}}{Q} = \frac{1}{1-k}[\gamma - \bar{\beta}]$. (For the exact definition of $\bar{\beta}$ and its sign, see equations (9) through (12), supra, p. 10.)

2. A water-saving technique directly affects productivity. Its adoption allows the group of farmers in question to operate as if their fixed amount of residual factor grew larger. It could be shown that a water-saving technique, so defined, is a neutral technological improvement expressed in terms of a rise in the general constant term of the production function underlying our model.[1/] As a rule, these improvements will always be adopted.[2/] Yet, an inquiry into their implementation within the framework of our model is inseparable from the analysis of technical change at large. In other words, water-saving techniques constitute one element in the aggregate referred to as the state of technology, the percentage change of which is summarized by the rate of technical change.

A Joint Technique.--A "joint technique" involving elements of water saving and water substituting at the same time is not inconceivable. In that case the change resulting in a higher level of productivity (due to water saving) will materialize if and only if it is associated with changes in factor substitutability. In other words, the implementation of a joint technique is reflected in an upward shift of constant term (α_o) conditioned by changes in the production elasticities (α_i) and vice versa. It could be shown that, in the longer run at least, the fate of a "joint" type innovation is essentially identical with that of water-substituting ones. The key element in this respect is the relative magnitudes of γ and $\bar{\beta}$, that is, the rates of percentage change in technology on the one hand and the variable factors' relative price on the other.

[1/] This will be the case regardless of any specific factor-use intensity.

[2/] The condition for implementation requires the analogues of r_t' and r_t^* in the present case to be larger than one.

Marginal Returns to Water in Israel's Agriculture

Applying the formulae of our simplified model in the "real world," we are aware of the serious, if not prohibitive, difficulties involved. Most important in the particular case under study is the assumption suggesting that, for factors other than water, MVP equals price. This assumption is closely related to the fundamental question of factor mobility. Another source of difficulty is the problem of aggregation.

Factor mobility--namely, labor mobility--is discussed in the next section in some detail. The estimates considered in the following sections have been derived at the highest level of aggregation--the industry's level. No attempt is made to correct the effects of, let alone to "solve," the aggregation problem. However, the industry level approximations--intended to indicate an order of magnitude--are verified by way of comparison with estimates derived at lower levels of aggregation, in some cases down to the farm level.

Rates of Factor Remuneration

The estimation of residual marginal values through the prescribed procedure requires the specification of an appropriate series of rates of factor remuneration. Particularly important in this respect, at least from a practical point of view, are the prices attached to the services rendered by the farm labor force.

Farm Labor Remuneration.--Due to the high percentage of self-employed among farmers, a substantial portion of the farm labor remuneration is not an observable entity. Thus, the farm labor wage rate is an implicit rather than an explicit rate. Furthermore, the farm wage rate should be considered in terms of real opportunity costs. Thus, an inquiry into the availability of jobs outside farming and the farm labor mobility seems to be indispensable.

Where real alternatives appear to be scarce, either due to the scarcity of nonfarming employment opportunities or as a result of insufficient mobility, farm labor remuneration is sometimes identified with the costs of "subsistence"--an approach summarized and criticized by Eckstein.[1] Yet, neither this approach nor the one implied by the following statement will suffice in the case of Israel. Concerned with water problems in southwestern United States, Howe suggests that "labor and capital in irrigation areas may be immobile over substantial periods of time once the areas have been developed. . . . The opportunity cost of these factors is zero over the periods of their immobility--the life of capital equipment, now in place and perhaps as much as a generation in the life of labor. . . . Under the circumstances of labor and capital immobility, the entire value added by irrigated agriculture and related agribusiness must be attributed to water."[2]

For some "circumstantial" evidence, at least, the Israeli farm labor force impresses its observers as being integrated in the general socioeconomic system of that country. The farm labor force in Israel amounts to approximately 100,000 man-years, accounting for 12 percent of the entire labor force in that country. In the last decade the farm labor force in Israel has been declining--in absolute terms--at an "average" rate of approximately 1,500 man-years per year. At the same time the average annual increment to total employment amounted to approximately 25,000 man-years. The last item could be looked upon as an indication of the availability of new jobs outside farming. Hence, out-migration from agriculture constitutes an insignificant magnitude as compared with the annual addition of new jobs in the Israeli economy.

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[1] Otto Eckstein, Water Resource Development (Cambridge: Harvard University Press, 1958), pp. 198-200.

[2] C. W. Howe, "The Economic Issues in Interbasin Water Diversion," Western Farm Economics Association Proceedings, 1967, Paper presented to the Annual Meeting of the Western Farm Economics Association, Las Cruces, New Mexico, July 19-21, 1967 (Amherst: University of Massachusetts, 1968), p. 211.

The availability of employment opportunities outside farming is coupled, in the case of Israel, with the lack of a clear-cut distinction between rural farming regions and the urban-industrial centers.

Almost one-fifth of the Israeli farm labor force is comprised of members of cooperative settlements--the kibbutzim. The following table (Table 1) verifies this point. Yet, only 40 percent of the self-employed members of these cooperatives are engaged in farming. The 60 percent of the cooperative membership not accounted for by Table 1 is equally divided between public and personal services for the local community and commercially oriented services and industries. The cooperatives are, in fact, highly advanced agroindustrial organizations which maintain an unusual degree of diversification within the broad limits of their enterprises. Since this economic organization was set up within the lifetime of one or two generations, beginning with settlers with no skills in farming or industrial training and eventually ending up with a diversity of enterprises, flexibility and mobility must have been crucial elements in its social infrastructure.[1] Internal mobility, coupled with labor inflow and outflow at the industrial end of the organization, tends to result in implicit wage rates--that is, values of the marginal product of labor which are at least as high as the ones recorded as the "monthly salary" of the Israeli industrial worker.[2]

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[1] For a discussion of the intergenerational aspects of labor mobility, see Judah Matras, Social Change in Israel (Chicago: Aldine Publishing Company, 1965), pp. 156 and 159.

[2] For appraisal of the values of the marginal product of labor in the kibbutz, see Sadan, Capital Formation and Growth of the Kibbutz Settlement, pp. 106-111.

Israel, Bank of Israel, Annual Report, 1966 (Jerusalem, 1967), p. 242.

Israel, Central Bureau of Statistics, Statistical Abstract of Israel, 1968 (Jerusalem, 1968), p. 292.

TABLE 1

Distribution of the Israeli Farm Labor Force in the Various Types of Settlements, 1967

Type of settlement	Farm labor	
	Number of persons employed in agriculture (1,000 man-years)	Percentage of total number of persons employed
Cities, towns, and urban settlements	27.0	4.0
Cooperative settlements (kibbutzim)	20.4	40.0
Family farms in moshovim	30.3	71.9
Other rural settlements[a]	26.5[b]	46.9

a/ Mainly Arab villages.

b/ Arab labor force--22.7.

Source: Israel, Central Bureau of Statistics, Statistical Abstract of Israel, 1968 (Jerusalem, 1968), p. 266.

Employees--that is, hired hands in agriculture--make up 40 percent of the Israeli farm labor force.[1] Most of these hired hands are classified in Table 1 as residents of cities, towns, and urban settlements where, on the average, farm employment accounts for a mere 4 percent of the overall employment figures. Their average monthly salary of farm employees is lower than that of the industrial worker. Yet, this wage differential could be attributed to qualitative differences traceable to the question of relative importance of Israeli-born and European immigrants among industrial workers and that of immigrants from the Middle East among farm employees.

We have considered so far two sections accounting for approximately one-half of the Israeli farm labor force. The remaining half consists of family farmers in the moshav settlements and Arab villagers. Disguised unemployment is more likely to occur, if at all, in these two sections. However, considering the moshav residents, it must be realized that a substantial number of them are living in the vicinity, if not in the midst, of the urban-industrial center of Israel. Table 2 is intended to clarify this point. The upper section of this table outlines the major characteristics of six regions of pre-1967 Israel, referring to density and the percentage of population in rural settlements. The lower section indicates the distribution of the moshav population in the various regions. We note that approximately one-half of the moshav population resides in the dense seashore industrial center. We should also note that a substantial portion of the Arab villagers live within the boundaries of that center.

The case of the moshav family farmers and Arab villagers is not as clear as that of the cooperative membership and the hired labor in agriculture. Yet, in view of the previous remarks, one should be aware of the long-run, if not

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[1] Israel, Central Bureau of Statistics, Statistical Abstract of Israel, 1968.

TABLE 2

Distribution of the Moshav Population in Urban and Rural Regions, Israel, 1967

	Distribution of population					
	Central seashore districts					
	Haifa and Tel Aviv "metropolitan" area[a]/	Sharon "suburban" area[b]/	District of Jerusalem[c]/	Inner valleys and the North[d]/	The South[e]/	The Deep South[f]/
	persons per square kilometer					
Population density						
Least dense subdistrict in the region	416	199	473	81	101	13
Most dense subdistrict in the region	4,833	360		180		
	percent					
Percentage of population in rural settlements						
Least rural subdistrict in the region	0.5	21.7	5.5	38.3	24.8	30.3
Most rural subdistrict in the region	15.9	39.7		60.1		
The region's "share" in the national moshav population[g]/	14.5	28.2	8.8	21.4	17.7	9.4

(Continued on next page.)

TABLE 2--continued.

a/ Includes the subdistricts of Haifa, Petah Tiqwa, and Rehovot and the district of Tel Aviv.

b/ Includes the subdistricts of Sharon, Ramla, and Hadera.

c/ Includes East Jerusalem; no division into subdistricts takes place in this region.

d/ Includes the subdistricts of Akko, Yizreel, Kinneret, and Zefat.

e/ Includes the Ashqelon area; no division into subdistricts takes place in this region.

f/ Includes the Beer Sheva area; no division into subdistricts takes place in this region.

g/ Inputed as the ratio--regional population of moshav settlements divided by the total national population of Moshav settlements (121,700).

Source: Israel, Central Bureau of Statistics, Statistical Abstract of Israel, 1968 (Jerusalem, 1968).

immediate, alternatives facing the Israeli farmer where farming takes place in the close boundaries of an industrial-urban matrix.

The Wage Rates Stipulated.--There is little doubt as to the appropriate wage rate to be attached to the services of hired labor in agriculture. As for the self-employed members of the cooperatives, various studies indicate that their implicit wage rate is at least as high as that of the industrial worker.[1/] Considering a proper rate for the bulk of moshav family farmers and the Arab villagers, we are inclined to believe that their average implicit wage rate is at least as high as that of hired hands in agriculture. Two alternative wage rates were stipulated in the following imputations. One was a weighted wage rate of the industrial and farm workers, the respective weights being 0.25 and 0.75. The second was the farm labor wage rate. The latter is a deliberate understatement of the real wage rate which, as suggested above, is bound to result in an "optimistic" appraisal of the marginal returns to water looked upon as the residual factor. Table 3 indicates the respective wage rate figures for 1965. For the sake of comparison, the table also presents the daily wage rates stipulated by the Farm Labor Union and the rates used in the imputations of the Israeli Farm Income Research Institute.

Factors Other Than Labor.--Preferring underestimated rather than overestimated values of the "average factor remuneration," the conservative "net stock" assessments of the stock of reproducible farm assets were adopted. The rate of interest was taken to equal the one paid by banking institutions to depositors on their "escalated" time deposits.[2/] This rate is a conservative

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1/ Sadan, "Problems of Development of Water . . ." and Capital Formation and Growth of the Kibbutz Settlement.

2/ Escalated savings carry interest and inflation premia. The inflation premia are imputed periodically according to the Central Bureau of Statistics price indices. Thus, the rate of 6 percent is a real rate of interest; see Ezra Sadan and Yair Kadishay, Financing Capital Formation in the Kibbutz Settlement, The Hebrew University of Jerusalem (Rehovot, Israel, 1967), pp. 29-31.

TABLE 3

Recorded and Stipulated Wage Rates, Israel, 1965[a]

	Recorded monthly salary	Recorded daily wage rate of farm labor	Farm union's wage scale	Farm Income Research Institute approximations[b]
	1	2	3	4
	Israeli pound			
Farm employees	280	11.7	11.4[c] - 19.5[d]	[e]
Industrial workers or self-employed in agriculture	460	19.2	[f]	20 - 25

[a] Quoted in IL per month or IL per day. Official exchange rate is one IL = 33 cents.

[b] Approximations of the implicit wage rates of self-employed.

[c] Lowest rate--"farm hand, temporary."

[d] Highest rate--"tractor driver, Class A."

[e] The Farm Income Research Institute accepts the recorded data when concerned with farm employees.

[f] This union is concerned with farm employees but not with industrial workers nor with the self-employed.

Sources:

Col. 1: Israel, Bank of Israel, Annual Report, 1967 (Jerusalem, 1968), p. 219, and Israel, Central Bureau of Statistics, Statistical Abstract of Israel, 1968 (Jerusalem, 1968), p. 242.

Col. 2: Recorded monthly salary divided by 24.

Col. 3: Israel, Central Bureau of Statistics, Statistical Abstract of Israel, 1968 (Jerusalem, 1968), pp. 295 and 296.

Col. 4: Ibid., pp. 343 and 344.

estimate, falling short of the rates stipulated on credit extended to the Israeli investors, particularly farmers in the mid-1960's. The contribution of land was completely overlooked, thus assuming that water is the only residual factor. This assumption may also be interpreted as suggesting that the price of the services of arable land is nil.

The Value Added

The element of equation (4) discussed so far is the average factor remuneration. The other element in that equation is the value of the average product. The value of the product adopted in our imputations is the "value added" which stands for the contribution of the farm sector to the net national product. The value added is imputed as the difference between the value of the total farm produce on the one hand and a depreciation allowance and the value of the services and raw materials utilized by the farm sector on the other. These items are materials and services, as well as intermediate goods, purchased from other sectors but are not, for our particular purpose, value of water purchased by the farm sector from other sectors of the economy.[1]

Price Support and the Value Added.--"The direct benefits of crops that end up in storage is zero; the resources used up contribute nothing to the real national income." A rephrasal of this statement made by Eckstein with respect to water resource development in the United States applies in our case as well.[2]

As a result of price-support programs and price fixing, part of the farm product in Israel ends up in garbage piles (vegetables and bananas). Another portion (eggs) has been stored for a while and finally dumped abroad at a heavy loss to the government.[1] Yet, another portion was subsidized under deficiency payments of schemes (milk) which resulted in a two-price system.

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[1] Israel, Bank of Israel, Annual Report, 1966, Chap. 11, p. 260.

[2] Eckstein, op. cit., p. 200.

The value added could be imputed, therefore, in two different ways: (1) The value added, imputed at market prices, would reflect real sales (not including surpluses) imputed at market prices (not including subsidies) and (2) the value added at factor costs should reflect the income originated in the farm sector. As such, it includes, in addition to the value added at market prices, deficiency payments and government expenditures on purchasing surpluses for removal.

Values of the Marginal Product of Water

Values at Present; the National Level, 1961 and 1965.--Our "intermediate" estimates of the values of the marginal product of water, derived from data collected at the national level, fall in the vicinity of the gray market price referred to in the introduction. In 1965 the lower and upper limits of the values arrived at are 2.7 cents and 19.5 cents per 1,000 gallons. These are our low-low and high-high estimates, respectively, with the intermediate values varying around 11 cents per 1,000 gallons. The differences between high and low estimates stem from different assumptions as to the wage rate on the one hand and the value added on the other. Table 4 outlines the imputation procedure which, in terms of the verbal discussion, follows equation (4) above. The procedure involved is rather simple. Nevertheless, it seems desirable to trace the various steps taken in the imputation of at least one of the values indicated in that table. Consider, for instance, the imputation of the returns to water in 1961. The contribution of the farm sector to the national

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[1] Exporting in these cases was an inevitable but undesirable result of a domestically oriented scheme; see Israel, Ministry of Agriculture, "The Minister's Annual Report to the Knesset" (Tel Aviv, 1966).

TABLE 4

Values of the Average Product, Average Factor Remuneration and the Marginal Product of Water, Israel's Farm Sector 1961 and 1965

Year and value of the average product of water[a]	Average factor remuneration[b]			Value of the marginal product of water[e]	
	Farm real assets	Farm labor			
		Low[c]	High[d]	High[f]	Low[g]
	agorot per cubic meter (cents per 1,000 gallons)				
1961					
At factor costs					
47.5[h]	7.9	27.4	33.0	12.2	6.6
59.4[h][i]	9.9	34.2	41.2	15.3	8.3
At market prices					
42.8[h]	7.9	27.4	33.0	7.5	1.9
53.5[h][i]	9.9	34.2	41.2	9.4	2.4
1965					
At factor costs					
69.1[i]	11.6	38.0	45.9	19.5	11.6
At market prices					
60.2[i]	11.6	38.0	45.9	10.6	2.7

(Continued on next page.)

TABLE 4--continued.

a/ $\frac{(W_{ot}/W_{oo})\ x_{ot}}{x_m}$ in equation (4).

b/ $\frac{W_{it}\ x_{it}}{x_m}$ in equation (4).

c/ Applying the farm employees' wage rate.

d/ Applying a weighted average of the farm employees' and the industrial workers' wage rates, the weight being 0.75 and 0.25, respectively.

e/ V_{mt} in equation (4).

f/ Deducting the low labor remuneration figure.

g/ Deducting the high labor remuneration figure.

h/ Including 3.8 agorot per cubic meter payments on water to other sectors.

i/ All the values indicated along the line, thus marked, equal their respective current price values, inflated by 1.25, which is the ratio of the farm product price level in 1965 to the corresponding level in 1961. Other values are presented in current prices.

j/ Including 4.7 agorot per cubic meter payments on water to other sectors.

Sources:

Ezra Sadan, "Problems of Development of Water Resources in Israel," Economic Quarterly, Vol. 14, No. 54-55 (October, 1967) (in Hebrew).

Israel, Central Bureau of Statistics, Statistical Abstract of Israel, 1966 (Jerusalem, 1967).

Israel, Bank of Israel, Annual Report, 1965, Chap. 11 (Jerusalem, 1966).

income in 1961 was 447.9 million IL (Israeli pounds; 33 cents = one IL). The water endowment for that period was 1,025 million cubic meters. Dividing the former item by the latter, we have a figure of 43.7 agorot per cubic meter (an agorot is 1/100 of an IL). Adding to that figure, 3.8 agorot--the average payment for the acquisition of water made by the farm sector to other sectors--we reach the value of the average product of 47.5 agorot per cubic meter indicated in Table 4. Inflating this value by a conversion factor of 1.25, we have the value of the average product of 59.4, measured in agorot per cubic meter at the 1965 farm product price level, which is equivalent to 59.4 cents per 1,000 gallons.[1]

Remuneration of farm real assets in 1961 is imputed as 6 percent of the value of a net stock of 1.35 billion IL. Divided by the water endowment, the farm real asset "average remuneration," as indicated in Table 4, amounts to 7.9 agorot per cubic meter in current prices or 9.9 agorot per cubic meter at 1965 farm product price level--thus, 9.9 cents per 1,000 gallons. Total employment in 1961 amounted to 122,000 man-years or 0.0234 man-days per cubic meter of water. At a daily wage rate of 11.7 IL per man-day (Table 3), low estimate of "average labor remuneration" is 27.4 agorot per cubic meter or 34.2 agorot per cubic meter at the farm product price level of 1965--that is, 34.2 cents per 1,000 gallons. Finally, the "high-high" estimate value of the marginal product of water in 1961 amounts to 15.3 agorot per cubic meter or cents per 1,000 gallons (1965 price level). This is the difference between the value of the average product measured at factor costs (including subsidies) and the average remuneration due on farm real assets and the low estimate of the average labor remuneration.

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[1] Due to a mere coincidence, values expressed in agorot per cubic meter at the 1965 price level are visualized as if they were measured in cents per 1,000 gallons. The 3.8 factor applied in the conversion of meters into thousands of gallons falls in the proximity of the most frequent effective exchange rates of IL per dollar applied in the case of farm products during the 1965 period. Note that a series of effective rates rather than a single official rate is involved.

It should be emphasized that the procedure of converting values which are originally imputed in current prices does allow for changes in the real, that is, relative prices of the factors of production. Let V_{mt}' stand for the approximated value of the marginal product of water in year t, measured at the 1965 farm product price level, then:

$$V_{mt}' = \frac{W_{0,65}}{W_{0,0}} V_{mt} = \frac{(W_{0,65}/W_{0,0})\, x_{0t}}{x_{mt}} - W_{0,65} \sum_{i=1}^{m-1} \frac{(W_{it}/W_{0t})\, x_{it}}{x_{mt}} .\text{[1]} \qquad (16)$$

The Industry-Level Approximation and Estimates Derived at Lower Levels of Aggregation.--The industry-level approximation which refers to the value added at factor costs--that is, 11.5-19.5 cents in 1965--is comparable with the 15 cents per 1,000 gallons gray market price mentioned above and thus compares with estimates derived at lower levels of aggregation by Yaron and his associates.[2] Yaron's comprehensive study involved, to a certain extent, "positive" estimation procedures, such as residual-value approximation and regression analysis, applied at the farm and the subregional levels, respectively. The essence of the study, however, is an extensive reliance upon mathematical programming applied at various levels from the intrafarm to the national interregional level. Summarizing the outcome of this endeavor, Yaron suggests that the critical values of the marginal product of water fall within the range of 19-25 agorot per cubic meter at the 1965 farm product price level--that is, approximately

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[1] See equation (4), *supra*, p. 8.

[2] Yaron, *op. cit*.

19-25 cents per 1,000 gallons.[1] Thus, our high-high approximation seems to fall in the vicinity of Yaron's lower limits. In other words, our estimates are somewhat less optimistic than his. This discrepancy may be ascribed partly to the difference between ex post analysis and ex ante programming, but it may also be attributed to the nature of industry-level approximations as compared with Yaron's critical values mentioned above. The former are crude nationwide averages, the latter being a reflection of marginal returns to water attainable through the "marginal" group of agricultural products, namely, field crops in a marginal region, such as Israel's southern districts (Hadarom). In both cases the margins referred to are the "extensive margins." Field crops assume this position by virtue of having a perfectly elastic demand curve due to the fact that Israel, as a small buyer or seller, can acquire or dispose of any feasible quantity on the respective international markets at given prices. As for the southern districts of Israel, these are located in the more arid regions of that country--at the foremost receiving end of the National Carrier. The probable nature of a nationwide average and, to an extent, the discrepancy between ex post and ex ante approximation are reflected in Table 5, which presents two series of estimates of the values of the marginal product of water in various regions of Israel. The series presented in the first column of this table is that of Yaron's study. The second column presents a paralleling series of residual value approximations, derived from data collected at the farm level in the existing cooperative farms in the various regions.[2] Also presented are the anticipated 1970 average supply

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[1] For additional references, ibid., pp. 7 and 63.

[2] The data were collected in 1961. It is assumed that the omission of the technologically less-advanced, noncooperative units is being counterbalanced by the difference between the 1961 and the 1965 technology.

TABLE 5

Values of the Marginal Product and the Average Supply Costs of Water in Various Geographical Regions, Israel 1961-1965

Region	Estimates of the values of the marginal product of water		Anticipated average total supply costs[a]
	Yaron	Residual values	
	1	2	3
	agorot per cubic meter (cents per 1,000 gallons)[b]		
Upper Galilee	14	14	[c]
Jordan and Bet Shan Valleys	6-18[d]	9-15	6-9
Jezreel Valley	22-34	26	16[e]
Coastal plain	20-33	13-14	10-15
The South (Hadarom)	21-32	19	20-41

[a] Quoted at the 1965 price level. Note that the figures presented are average total costs. The average variable costs amount to approximately 28 percent of the average total costs.

[b] Values quoted at the 1965 price level.

[c] Costs in this region are very low.

[d] Jordan Valley.

[e] Western Jezreel Valley.

Sources:

Col. 1: Dan Yaron, The Demand for Water by Israel Agriculture, Department of Agricultural Economics, The Hebrew University (Rehovot, Israel, 1966); for explanation, see *supra*, pp. 32 and 33.

Cols. 2 and 3: Ezra Sadan, "Problems of Development of Water Resources in Israel," *Economic Quarterly*, Vol. 14, No. 54-55 (October, 1967).

costs of Israel's largest water supplier--Mekorot Company, Ltd.--imputed by the Israel Water Commission, Office of Economic Advisors.[1]

Future Trends in the Marginal Returns to Water

Following the discussion in the previous section, we are inclined to suggest that, at least, an order of magnitude could be established through the immediate and simple procedure of industry-level approximation. In this section an attempt is made to assess the future trends in the residual value at the industry level, looked upon as the water's share in agriculture's value added.

The Pace of Change, Technology, and Wage Rates.--Israel is, in fact, a developed economy. Applying T. W. Schultz's classification, this label is meant to imply that Israel belongs to the group of "low food drain" countries which are more likely to encounter a "farm problem" than a "food problem." In the complex of interrelated phenomena characterizing this group are two specific characteristics of immediate interest to us. First, we note the 6 percent annual level of the rate of agrotechnological improvement in Israel. This greatly exceeds the 3 percent rate of technical change in Israel's economy as a whole.[2] The second, and an interrelated phenomenon, is the so-called deterioration of the terms of trade of agriculture. For our purposes, a comparison of the pace of the farm product price level and that of the rate of labor remuneration will suffice. We note that the farm product price level rose from 1961 to 1966 by 30 percent; at the same time, both the farm labor and the industrial workers' wage rates rose by approximately 85 percent.[1] Thus, the real farm labor wage rate rose 42 percent in a six-year period. This may be interpreted as a 7.5 percent average annual rate of change in the real farm wage rate.[2]

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[1] For details and references, see Sadan, "Problems of Development of Water Resources. . . ." Mekorot is a publicly owned corporation engaged in the supply of water for farm and nonfarm purposes from existing national, regional, and local water sources. Mekorot supplies three-fourths of the total annual supply of water in Israel. The remaining one-fourth is carried by smaller corporations and unincorporated enterprises.

[2] Israel, Economic Planning Authority, op. cit., pp. 5 and 327.

A study of the growth pattern of the cooperative farm from 1936 to 1960 reveals an identical rate of agrotechnical change of 6 percent annually; see Sadan, "Capital Formation and Growth of the Israeli Cooperative Farm."

The Rates of Change in the Marginal Returns to Water.--Dividing the value of the marginal product of water in 1961 or 1966 by the corresponding value of the average product, we find that the relative factor share of water in agriculture's value added is approximately .18. The corresponding share of farm labor is .64.[3] These estimates of the respective factor shares and the approximation of the rates of change in technology and the real wage rate enable us to gauge the rate of the change in the value of the marginal product of water-applying equations (10) and (15).

Employing equation (15), it is assumed that the observed rate of change in the farm labor real wages may represent the rate of change of the weighted real factor price.[1] Thus, the following approximations were inserted into equation (12): $\alpha_m = .175$, $\gamma = .06$, and $\bar{\beta} = .075$. The estimated rate of change in the value of the marginal product of water in that case is nil:

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[1] According to Israel, Central Bureau of Statistics, Statistical Abstract of Israel, 1968 and Israel, Bank of Israel, Annual Report, 1967 (Jerusalem, 1968), p. 219.

[2] The corresponding long-term rate is the following: In 1960 the industrial worker's "real wage rate" was 3.5 times higher than the corresponding rate in 1936; see Sadan, Capital Formation and Growth of the Kibbutz Settlement, p. 108. Hence, "real wages," imputed as the ratio nominal wage rate/consumer price index, rose at the annual rate of 6 percent. Real wages, defined as the ratio index nominal wage rate/farm product price index, rose at a somewhat higher annual rate.

[3] Referring to values at market prices and to the low estimate of the average labor remuneration in 1961, the factor shares of water and labor are .175 and .64, respectively (Table 4, supra, p. 24; see, also, supra, p. 31). The corresponding shares in 1965 were .176 and .63.

$$\frac{\dot{V}}{V} = \frac{1}{.175} [.06 - .825 \cdot .075] \simeq 0.$$

This estimate may be referred to as a lower limit. Assuming that the rate of change of the real prices of factors other than labor is nil, we arrive at another estimate which may be referred to as the respective upper limit where

$\alpha_m = .175$

$\gamma = .06$

$\alpha_{labor} = .64$

and

$\beta_{labor} = .075.$

$$\frac{\dot{\bar{V}}}{V} = \frac{1}{.175} [.06 - .69 \cdot .075] \simeq .07,$$

that is, the annual rate of change in the value of the marginal product of water amounts to 7 percent.

If it were not for the high values of either β_i or $\bar{\beta}$, the marginal returns to the residual factor--water--would have been rising at the annual rate of 34 percent (according to equations (10) and (15)). Compared with this high rate, the upper limit of 7 percent, despite the lower limit, manifests the importance of the coefficients β_i or $\bar{\beta}$. Each of these coefficients referred to above as measuring the "deterioration" in agriculture's "terms of trade" may be regarded as consisting of two components. One component is the "true" rate of deterioration in the terms of trade, the other one being a correction term which, indicating a qualitative change in the respective factor or factors of production, is deductible from γ--the rate of (disembodied) technical change. In other words, it may be suggested that changes in the real remuneration per units of a productive service--where units are defined and measured in unsophisticated terms, such as man-years--is partly due to changes in the potential of the unit. An inquiry into the nature of β or γ along these lines clearly falls beyond the scope of this article. For our purposes, it will suffice to point out that the conventional estimates of technical change, such as the ones presented by Israel's Planning Authority, are subject to a substantial reduction when applied in the assessment of the rate of change in marginal returns to a residual factor. This will be the case, either because of the deterioration of the terms of trade, or because the rates presented are overstated to begin with, or for both reasons.[1]

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[1] $\bar{P}$ in equation (11), supra, p. 10.

The Values of the Marginal Product of Water, 1961-1966.--One way to illustrate the effect and countereffect supposedly attributable to technical change and the deterioration of the terms of trade, respectively, is to compare two time series of the values of the marginal product of water. One series will consist of residual values imputed according to equation (16) which underlies the imputation in Table 4. Another series will be calculated according to the following equation (17) which rules out changes in the real prices of the factors of production:

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[1] A 6 percent annual rate of disembodied technical change characterizes, we recall, the long-run growth pattern of the cooperative settlement as well as the industry as a whole. Yet, in the case of the former group, it could be shown that 4 of the 6 percent is attributable to factor-augmented technical change; see Sadan, "Capital Formation and Growth of the Israeli Cooperative Farm."

$$V_{mt}^{*} \frac{(W_{0,65}/W_{0,0})\ x_{0t}}{x_{mt}} - W_{0,65} \sum_{i=1}^{m-1} \frac{(W_{i,61}/W_{0,61})\ x_{it}}{x_{mt}} . \tag{17}$$

The new variable, V_{mt}^{*}, is the value of the marginal product measured at the 1965 farm product absolute price level and referring the relative prices of 1961 regardless of t. The selection of either 1965 or 1961 is, of course, arbitrary.

Equation (17) is related to equation (16) as follows:

$$V_{mt}^{*} = V_{mt}' + \sum_{i=1}^{m-1} C_{it} \tag{18}$$

where C_{it}, a "correction term," = $C_{it} = W_{0,65} \left(\frac{W_{it}}{W_{ot}} - \frac{W_{i,61}}{W_{0,61}} \right) \frac{x_{it}}{x_{mt}}$.

Imputing the series illustrated by a broken line in Figure 1, it is assumed that the only nonzero correction term is the one pertinent to farm labor. Thus, the difference between the two series illustrated by Figure 1 is traceable to the rise in the real wage rate.

The series illustrated in Figure 1 was imputed at market prices. According to Table 4, the subsidy per 1,000 gallons grew from 5.9 cents in 1961 to 8.9 cents in 1965. This 51 percent rise is far ahead of the 12 percent increase in the value of the average product at market prices during the same period. Selecting values of the average product pertaining to market prices rather than at factor cost, the immaterial effect of a rise in subsidies is left out. The slight effect of a rise in subsidies is omitted.

Figure 1 seems to substantiate the proposition made in the previous section suggesting that the effect of technical change on the marginal return to a residual factor is offset by countervailing effects inherently present in the economic system.

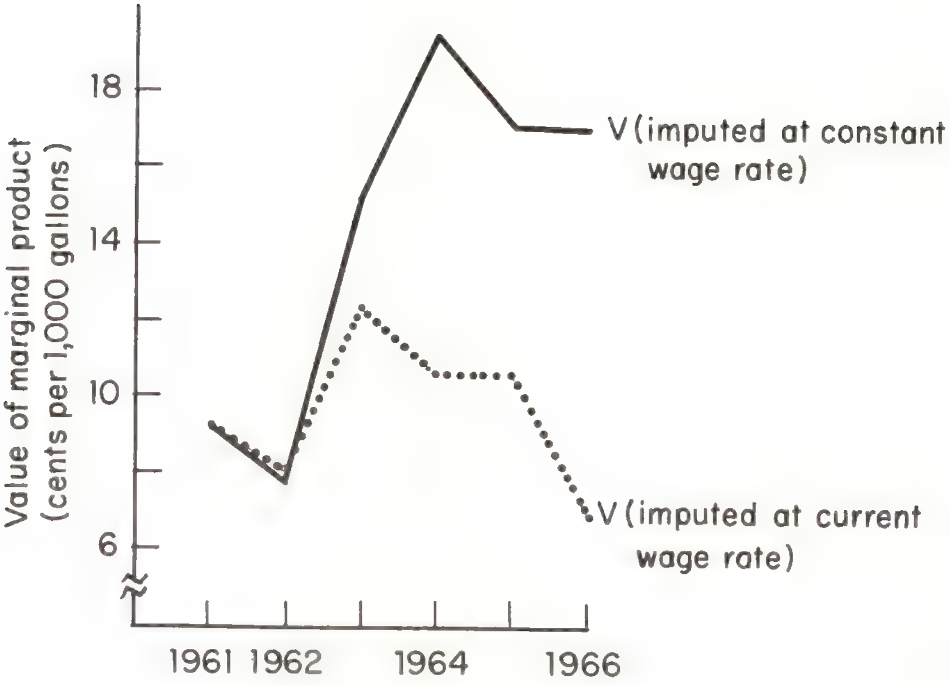

FIGURE 1. The Values of the Marginal Product of Water, Israel, 1961–1966 (measured at the 1965 farm product price level in Israel)

Water Substitution.--Changes in the residual factor share between 1961 and 1965 are negligible (adopting the high estimates at factor costs in Table 4, the share is 17.6 percent in both periods). Since the rate of change in the farm inputs' price level exceeds the rate of technical change, that is, $\bar{\beta} > \gamma$, dramatic developments in water saving involving water substitution seem unlikely in the foreseeable future.[1]

The Accuracy of the Estimates Arrived At--The Limitation of the Model

As mentioned at the outset of this section, the application of one model in the real world involves some serious difficulties. Most serious in this respect are the ones associated with the model's fundamental assumption suggesting that MVP = price for factors other than water. Applying this model in the real world where MVP $\neq$ price, one is necessarily concerned with a host of specification errors in addition to some inevitable errors of measurement. A review of the possible sources of errors in these respects is summarized by the following short remarks:

1. Our most conspicuous error of specification concerns the land variable which was simply omitted from our imputations as if, in that case, MVP = P = 0. Returns to land were, therefore, clearly underestimated.
2. Considering capital we note that (a) imperfections in the capital market (external rationing) and (b) the lack of knowledge linked with risk aversion (internal rationing) could have resulted in MVP > price in that case. The result may have been an underestimation of the returns to capital.

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[1] Changes involving "pure" water-saving techniques are accounted for by the rate of technical change at large.

Considering the most important factor--labor--we note that a situation where MVP < price commonly develops in that case as a result of labor immobility. In view of the detailed discussion above, this is not likely to be the case in Israel's farm sector. Furthermore, for good measure we have stipulated relatively low and most probably understated wage rates. As a result, our estimate of returns to labor is most likely to be underestimated.

In summation, our estimates of the returns to factors other than water appear to be downward biased. However, in view of our somewhat skeptical propositions regarding the magnitude of the value of the marginal product of water in Israel, it seems reasonable to prefer an underestimation rather than overestimation of the rates of factor remuneration. An underestimation in this respect is bound to result in overstated residuals, thus in an overestimation of the values of the marginal product of the residual factor.

Another source of difficulties is inter- and intraregional disparities in the marginal returns to the residual factor resulting from the rigidities of the institutional setup. Under the circumstances the estimate arrived at may be looked upon as an average value reflecting the relatively low returns in areas with "water surpluses" and the relatively high returns in areas suffering "water shortages."1/

In accord with the "law of diminishing returns," we assume that the average in question falls short of the value which could have materialized under conditions of perfect water mobility.

1/ The latter values are sometimes presented as indicators of the national extensive margins under the assumption of "given institutional conditions." The dubious nature of this approach with reference to a similar case is discussed in the section concerning intangible returns in the following section; see infra, p. 47.

Apart from the particular difficulty just described, our estimation procedure and the estimates arrived at are subject to errors and biases associated with aggregation in general. For instance, applying aggregates, we are implicitly assuming that the arrays of relative prices underlying the aggregation procedure are given. Hence, our intertemporal comparisons should be limited (as they were) to time periods which allow for this assumption. Our predictions are also limited by the assumption that future relative prices--the prices of industrial crops relative to dairy products, for instance--will resemble their corresponding analogues today.[1]

Many, if not all, of these difficulties could be resolved should an attempt at a detailed analysis be carried on at a lower level of aggregation. However, even then, one would expect the results of such an elaborate endeavor to be consistent with the national accounting figures. In other words, "micro" estimates could be suspected if not rejected unless they fell in the vicinity of the "macro" estimates presented above. In that respect, the latter could be referred to as a reliable measurement of an order of magnitude.

The Benefits of a 100 MGD Desalting Plant

Tangible Primary Benefits

The primary benefits attributable to an addition of 100 MGD of desalted water to Israel's water supply consist of "quantitative" and "qualitative" elements. The primary quantitative element is the additional output ascribable to the additional water supply as such. The primary qualitative benefit is attributable to the quality of the additional water supply which is salt free and thus may be used as a dilutant. In reducing the salt content of the total water supplies in a given area, the introduction of a dilutant is bound to serve as a replacement for the leaching of irrigated soils and for water softening for industrial use as well as for eliminating some crop damage.

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[1] For instance, a sharp decline in the relative price of industrial crops might have resulted in a change in the aggregated output and a corresponding change in factor shares. Thus, should this relative price change sharply between 1961 and 1965, it could have invalidated the comparison made in the last paragraph of the previous section. In reality, however, changes in the key relative prices during the period in question were rather mild; see Israel, Ministry of Agriculture, The Minister's Annual Report to the Knesset (Tel Aviv, 1966).

The Primary Quantitative Benefits.--The proposed addition of 100 MGD to Israel's conventional water supplies may be directed to agricultural or industrial and municipal use. Either way, it is envisaged as a 10 percent change in the existing water supply for agricultural use. In other words, considering the array of marginal returns to water in the Israeli economy, agriculture is looked upon as the "extensive margin." Contemplating an allocation mechanism which is efficient enough to prevent gross misallocation--at the interindustrial and interregional levels, at least--the proposed addition of 100 MGD is expected to add 10 percent or less to the water supply for agricultural uses or, alternatively, prevent a future decline of equal magnitude. Should this increment be dispersed among the various users of the existing supplies of water for agricultural use, there would be good reason to believe that the level of marginal returns to water would vary within the limits specified by Table 4. In other words, we anticipate a primary quantitative benefit of the magnitude of 11 cents at market prices or 19 cents at factor costs per 1,000 gallons. In view of the mitigating effect of the perennial rise in the real farm wage rates, very little change in these rates is anticipated for the near future despite the persistent pace of agrotechnological improvement.

The proposed location for the desalting plant is the southern part of Israel. It might be pointed out, therefore, that our industry-level approximation at factor costs falls very close to Yaron's lower estimate and our own estimate for that district.[1]

In their inquiry into the benefits of an Israeli-United States desalting project, MacAvoy and Peterson arrive at the optimistic conclusion that the primary quantitative benefit amounts to 24.1 cents per 1,000 gallons.[2] Yet, this relatively high value is the outcome of a strong assumption (apparently unintended) suggesting that the opportunity cost of the self-employed in the farm labor force is nil. Assuming that the self-employed were implicitly remunerated at the farm employees' wage rate level, MacAvoy and Peterson's estimate drops from 24.1 to 9.4 cents per 1,000 gallons (see Appendix for details).

The Primary Qualitative Benefits.--As a result of an elaborate attempt to quantify the anticipated qualitative primary benefits, MacAvoy and Peterson suggest that the additional income attributed to the desalted water as a dilutant amounts to 5.2 cents. This estimate is also consistent with the assumption that the opportunity cost of the self-employed is nil. Reimputed, subject to the more realistic assumption suggesting that the self-employed were implicitly remunerated at the farm employees' wage rate level, the net return to desalted water as a dilutant amounts to 3.9 cents per 1,000 gallons.

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[1] The values indicated by Table 5, *supra*, p. 34, are 21 and 19 cents per 1,000 gallons, respectively. We note that our estimate, at least, is based upon the assumption that the opportunity cost of land is nil. Relaxing this assumption, we have been able to fit a Cobb-Douglas type production function, which included land as well as water as explanatory variables, to data collected in 25 cooperative farms in the southern districts in the four-year period of 1958-1961. The values of the marginal product of water arrived at through the regression analysis ranged within the limits of 11 to 13 cents rather than 19 cents per 1,000 gallons at factor costs; see Sadan, "Problems of Development of Water Resources in Israel."

[2] P. W. MacAvoy and D. F. Peterson, *The Economic Engineering of Gorge Scale Desalting*, Alfred P. Sloan School of Management Working Paper, Massachusetts Institute of Technology (Cambridge, 1968), 134p.

The figure presented in the above report is $6.7 million, which is equivalent to 18.4 cents per 1,000 gallons. We have corrected this figure for an error of imputation, thus arriving at 24.1 cents per 1,000 gallons (Appendix, see *infra*, p. 54, for details).

Another approach to the qualitative aspect of the primary benefits is to consider the desalted seawater as a possible dilutant for reclaimed sewage water.[1] Being salt free, desalted seawater may enable the management of the water system to add reclaimed water with high salinity to the general flow without changing the prevailing salinity level. A prerequisite for the assessment of the benefit incurred is a clear answer to the following question: What is the degree of sewage water treatment, if any, deemed indispensable for sanitary reasons, and what is the price society is willing to pay for the prevention of pollution beyond that point? Unable to answer this question, we may, at best, indulge ourselves in speculation as to the upper limit of the benefit in question. We assume, therefore, that the reclamation of sewage water up to the dilution stage is deemed indispensable and is bound to take place even if the reclaimed water is economically useless. Thus, the primary qualitative benefit attributable to desalted seawater depends upon the coefficient of dilution.[2] Some experts speculate that the coefficient may be as high as two--that is, 1,000 gallons of dilutant per 1,000 gallons of reclaimed sewage water. Thus, the qualitative primary benefit equals the corresponding quantitative benefit which amounts, according to our imputations, to 11 cents per 1,000 gallons of desalted seawater. Being highly speculative, this figure, indicating an upper limit, should be considered with due reservation.[1]

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[1] Dan Mozes, "The Economics of Water Resources Development in Israel," and "The Economics of Desalting and Reclamation," Presented at the Seminar on Natural Resources Planning, University of New Mexico, Albuquerque, March 6, 1969, 11p. and 10p., respectively.

[2] This coefficient is intended to reflect the salinity level prescribed and maintained by Israel's water authorities today. This salinity level may or may not be the optimal one. A clarification of this point calls for an inquiry into the response function of plants to water quality.

Intangible Benefits

Population Dispersal.--A social goal most commonly mentioned in connection with a desalting project for Israel is population dispersal.[2] In a statement reflecting this common notion, MacAvoy and Peterson suggest, "There are political and cultural reasons for national allotments of capital and settlement of workers into dispersed agriculture in Israel.[3] The land has to be settled in order to hold the frontiers of the country, and it should be settled, according to the 'national will' of the 1960's, as part of a new way of life. . . ." Following this argument, MacAvoy and Peterson treat the capital allotted to and labor settled in Israel's South as if these were, for political reasons, perfectly immobile. Hence, proposing that the opportunity costs of labor and capital in that region are negligible, they attribute the entire value added produced in the region to the scarce resource--water. Assuming that the value added per 1,000 gallons is higher than the supply cost of 1,000 gallons of desalted water, they suggest that the difference between the former and the latter is a measurement of potential intangible benefit due to the water desalting project intended to supply water to Israel's South. Their mean estimate amounts to 8.2 cents per 1,000 gallons.[4]

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[1] The decision concerning the projects of desalting and reclamation may, of course, be inseparable. We also note the possibility that reclamation and dilution are substitutable to a certain extent. In either case, this speculative imputation may be inaccurate.

[2] Population dispersal is the most commonly mentioned "noneconomic" goal associated with seawater desalting. Yet, subject to rephrasal, the arguments raised in this section are equally applicable in the case of other noneconomic goals, such as the settlement of refugees for instance.

[3] MacAvoy and Peterson, op. cit., p. 119.

[4] Ibid., p. 123.

Intraregional Factor Mobility.--MacAvoy and Peterson explicitly address themselves to a group which includes a substantial number of cooperative settlements. Their suggestion that the opportunity costs of labor for farming are nil seems inappropriate. In the long run, at least, the cooperative settlements should be looked upon as agroindustrial enterprises. Even if labor and capital are assumed to be immobile at the interregional level--assuming that income discrepancies would have resulted in factor outmigration from the South--there is no reason to rule out intraregional mobility.

Considering the national will, we note that labor may be committed to the South in order to accomplish a social goal, but it will not necessarily be confined to farming for that purpose. Contemplating the possibility of industrial development in the southern cooperatives, we can see no reason why these should differ from their counterparts--the veterans of population dispersal and frontier settlement as well as of industrialization in the North.

Settlement of the South or the Preservation of Institutional Rigidities.--The value of the intangible benefit attributed to 1,000 gallons of desalted water is, according to MacAvoy and Peterson, 8.2 cents. This value, we recall, is the difference between the value added and the water supply costs per 1,000 gallons. Following the same line of reasoning and the same procedure, one may suggest that the relocation of 1,000 gallons from the Coastal Plain to the South will render an intangible benefit which will be three times as high as the one attributable to desalted water.[1/] One may ask, therefore, why should Israel indulge herself in producing intangible benefits through desalting at the rate of 8.2 cents rather than materialize, through relocation, an intangible

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[1/] According to Table 5, the opportunity costs of water in the Coastal Plain is 15 cents (at factor costs!) per 1,000 gallons. The difference between this amount and the 40 cents per 1,000 gallons cost of desalted water at the plant gate is 25 cents. Even if we deduct 9-10 cents for extra conveyance costs, the relocation is bound to render 24 cents per 1,000 gallons.

benefit worth 24 cents per 1,000 gallons. It might be suggested, of course, that relocation involves some intangible losses. In other words, Israel's national will might be reinterpreted to include a clause ruling out the possibility of acquiring water rights from their present holders in the Coastal Plain and diverting the released quotas through the existing national water carrier to the South. It must be emphasized that this course of action does not involve coercion or confiscation. The procedure of relocation and the relevant calculations contemplated above are consistent with a practice of acquiring the water rights from their present holders at a price representing the present value of their foregone incomes in the future. Hence, the national will must be concerned with the institutional framework as such. The society in question must place a positive value on the prevailing rigidities.[1]

Following Ciriacy-Wantrup, it may be suggested that "benefit-costs analysis has relevance for an economic criterion of public resource development only under 'given' institutional conditions."[2] What is, therefore, the given institutional condition in the case under study? The two propositions stated below seem to indicate that this question could be answered in two different ways:

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[1] Preservation of institutional rigidities and opposition to their relaxation are more likely to reflect the will of the relatively small group of established functionaries of the existing framework rather than the so-called national will. Outside observers are likely to confuse the former with the latter. Furthermore, in the case of Israel, the prevailing institutional arrangements are not as rigid as they may appear to be. The underlying formal framework does not allow for relocation, and the opposition to that course of action is by no means established unanimously among the personnel of the water allocation mechanism.

[2] S. V. Ciriacy-Wantrup, "Benefit-Cost Analysis and Public Resource Development," in Economics and Public Policy in Water Resource Development, ed. by Stephen C. Smith and Emery N. Castle (Ames: Iowa State University Press, 1964), p. 13.

1. MacAvoy and Peterson Proposition--given the prevailing institutional rigidities, a desalting plant of 100 MGD will render 8.2 cents per 1,000 gallons as an intangible benefit associated with the national will to settle the South.
2. The Reverse Proposition--given (the extent of) the settlement of the South, a desalting plant of 100 MGD will render 15.8 cents per 1,000 gallons as an intangible benefit associated with the national will to preserve the prevailing institutional rigidities.[1]

It is quite clear that, where the preservation of the institutional rigidities is not part of the national will, the second proposition is inaccurate. As for the first proposition, it retains its full validity where institutional arrangements are imposed upon the society with no reference whatsoever to the national will. If, however, the national will (expressed through public pressures) does result in the remolding of the system, the first proposition acquires a dubious meaning. There is good reason to believe that public pressures are positively associated with the loss incurred by the prevailing rigidities. Hence, the "given" condition in the first proposition is not really given. Given the institutional rigidities, desalting will allow for the accomplishment of a social goal--the settlement of the South. But, at the same time, it is bound to relieve the public pressure, thus helping to preserve the supposedly given conditions.

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[1] The amount of 15.8 cents per 1,000 gallons is the difference between the total gain of 24 cents in the case of relocation and the gain of 8.2 cents in the case of desalting. If desalting is preferred to relocation despite that difference, the implementation of the latter must result in an intangible loss. The magnitude of that loss must be at least 15.8 cents per 1,000 gallons. Given the extent of the settlement of the South, desalting will prevent relocation, preserve the rigidities, and produce an intangible benefit of that magnitude.

In other words, while it is commonly suggested that inflexibility may necessitate additional supplies, thus eventually resulting in desalting, the case may very well be that desalting eventually results in inflexibility. To the extent that the latter assessment is an accurate one, desalting will result in some gross intangible "spillover" losses of a substantial magnitude. Should these losses exceed the real social costs associated with the relaxation of the system as such, desalting will produce a net intangible loss.

Inappropriable Benefits

The implementation of a desalting plant in Israel may be looked upon as a large-scale field experiment. However, the technical and scientific knowledge rendered by this experiment is bound to become a free good in the international "public domain." A national economy can benefit from that free good to the extent that it utilizes the technical and scientific knowledge it represents. The magnitude of the benefits realized by the economy of a certain country is positively associated with the extent of utilization. The country's potential, in this respect, most probably reflects the size of its economy. In other words, some large national economies are more likely to become the beneficiaries of a large-scale field experiment in seawater desalting. If, for instance, the major achievement of the field experiment is a substantial reduction in the costs of constructing and operating a desalting plant, a country having the potential of constructing several plants is more likely to benefit from the experiment than a country with a potential to construct a single plant or none. Israel's potential is rather limited in this respect. Hence, the benefits attributable to a large-scale field experiment to be conducted in Israel are inappropriable from that country's point of view.[1]

Conclusion

It has been suggested that "whenever we can say that, on the basis of numerical estimates alone a particular project looks very good and the nonmeasurable factors point in the same direction, then we can be happy and satisfied."[2] Rephrasing this statement, we are inclined to suggest that, on the basis of numerical estimates alone, the Israeli-United States project does not look good. The nonmeasurable factors do not inspire confidence either. At present, at least, numerical estimates indicate a gap of 20-30 cents per 1,000 gallons between the primary benefits ascribable to, and the costs incurred by, water desalting. The major nonmeasurable factor, associated with the social goal of population dispersal coupled at the same time with the institutional rigidities, does not necessarily point in the right direction. Inasmuch as the institutional framework itself is not really a predetermined exogenous element, the implementation of a desalting project may result in intangible losses rather than gains to the society. Hence, at present, we are neither satisfied nor happy with the immediate implementation of seawater desalting in Israel.

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[1] Should the small country in question be a true underdeveloped country, it might have been suggested that the implementation of a large desalting plant is not only "experimental" but also "educational" in the sense that it is bound to introduce a section of that country's labor force to advanced and sophisticated technology. In the case of Israel the net effect in this respect is, at best, negligible. It may even be negative, depending upon the opportunities foregone.

[2] Fritz Machlup, Comment on "Preventing High School Dropouts," by Burton A. Weisbrod, Measuring Benefits of Government Investments, ed. by Robert Dorfman (Washington, D.C.: The Brookings Institution, 1965), p. 153.

As for the future, short of some unforeseen radical changes such as a major population influx, there is little hope for a substantial rise in the level of the marginal returns to water. Hence, the only hope for a satisfactory desalting project lies with an eventual decline in the cost incurred by seawater desalting.

APPENDIX

MacAvoy and Peterson's Estimates

Gauging the additional agricultural production which might be attributed to an increment of 100 MGD to Israel's water supply, MacAvoy and Peterson rely upon Mundlak's projections for 1975.[1] According to Mundlak, the additional agricultural production attributable to the said increment amounts to 64 million IL measured at the 1959 price level.[2] This value is a gross value rather than the value added, the former being the sum of the latter plus expenditures on raw materials and the depreciation allowance. Unfortunately, MacAvoy and Peterson overlooked the inflationary developments between 1959 and 1965, while converting Mundlak's figure into United States dollars. This error of conversion is corrected in Appendix Table 1, applying a correction factor of 1.31 derived from the farm product price index series.

A more serious flaw in MacAvoy and Peterson's calculations results from their erroneous estimate of the factor share of water in the gross value. Analyzing the industry level statistics of 1965, they suggest that the share of water in the gross value amounts to 31 percent.[3] This percentage is equivalent to a factor share of 50 percent of the value added. It is incompatible, therefore, with the figures presented in Table 4 which employ a factor share of half that size. The difference stems from MacAvoy and Peterson's imputation of the labor share in agriculture's gross value.

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[1] MacAvoy and Peterson, op. cit., pp. 82-88.

[2] Yair Mundlak, Long Term Projections of Supply and Demand for Agricultural Production in Israel, General View and Summary, Vol. I (Jerusalem: Falk Project for Economic Research in Israel, The Hebrew University, 1964), p. 198.

[3] MacAvoy and Peterson, op. cit., p. 85.

APPENDIX TABLE 1

Primary Returns from a 100 Million Gallons Per Day Desalting Plant
Israel, 1975

	Total net revenue		Net returns	
Source of returns	Original figures	Figures corrected for error of conversion	Figures corrected for error of conversion	Figures corrected for both errors[a]
	million dollars		cents per 1,000 gallons	
Additional agricultural output (high estimate)	6.7	8.8	24.1	9.4
Dilutant	1.9	1.9	5.2	3.9
Total	8.6	10.7	29.3	13.3

[a] Corrected for conversion error and the error in the calculation of labor's factor-share.

Source: Original figures obtained from P. W. MacAvoy and D. F. Peterson, *The Economic Engineering of Gorge Scale Desalting*, Alfred P. Sloan School of Management Working Paper, Massachusetts Institute of Technology (Cambridge, 1968), 134p.

Measuring this share at the industry level in 1965, they consider the sum of wages paid to farm employees as if it represents the total farm labor remuneration. This amounts to an apparently unintended introduction of the assumption that the opportunity costs of the self-employed are nil.

Labor's share in the gross value, according to MacAvoy and Peterson, amounts to 13 percent. Assuming that the self-employed--that is, the 60 percent of farm labor not accounted for--were remunerated at the farm wage rate level, MacAvoy and Peterson's labor factor share should be multiplied by $2.5 = \frac{1.00}{.40}$. The correct labor share is, therefore, 32 rather than 13 percent. The residual factor share should be corrected accordingly, thus arriving at 12 percent instead of 31; 12 = 31 - (32 - 13). The factor applied in order to correct MacAvoy and Peterson's estimates for the error in the factor share calculation is .39; $.39 = \frac{.12}{.31}$.

As for the contribution of the desalted water as a dilutant; part of it is the value of the saved leaching water.[1/] Assessing that value, MacAvoy and Peterson employ the marginal return of 25 cents per 1,000 gallons.[2/] Replacing the 25 cents by MacAvoy and Peterson's corrected estimate of the marginal returns, the relevant portion of the original value was corrected.

[1/] Ibid., p. 98.

[2/] The rate inserted is 19.7 agorot per cubic meter. Applying the official rate of 3.5 IL per dollar, this rate is equivalent to 25 cents per 1,000 gallons; see ibid., p. 110.